

## **Cone Penetration Testing for Seismic Hazards Evaluation in Memphis and Shelby County, TN**

**USGS Grant 00HQGR0025** (Feb 2000 to Feb. 2001)

Paul W. Mayne, PhD, P.E.  
Georgia Institute of Technology  
Mason Building, CEE 0355  
Atlanta, GA 30332  
Phone: 404-894-6226; Fax: -2281  
Email: [pmayne@ce.gatech.edu](mailto:pmayne@ce.gatech.edu); Internet: <http://www.ce.gatech.edu/~geosys/>

Program Element: CU

Keywords: liquefaction, borehole geophysics, probabilistic seismic hazards, geotechnical, paleoliquefaction, regional seismic hazards

### ***Annual Project Summary***

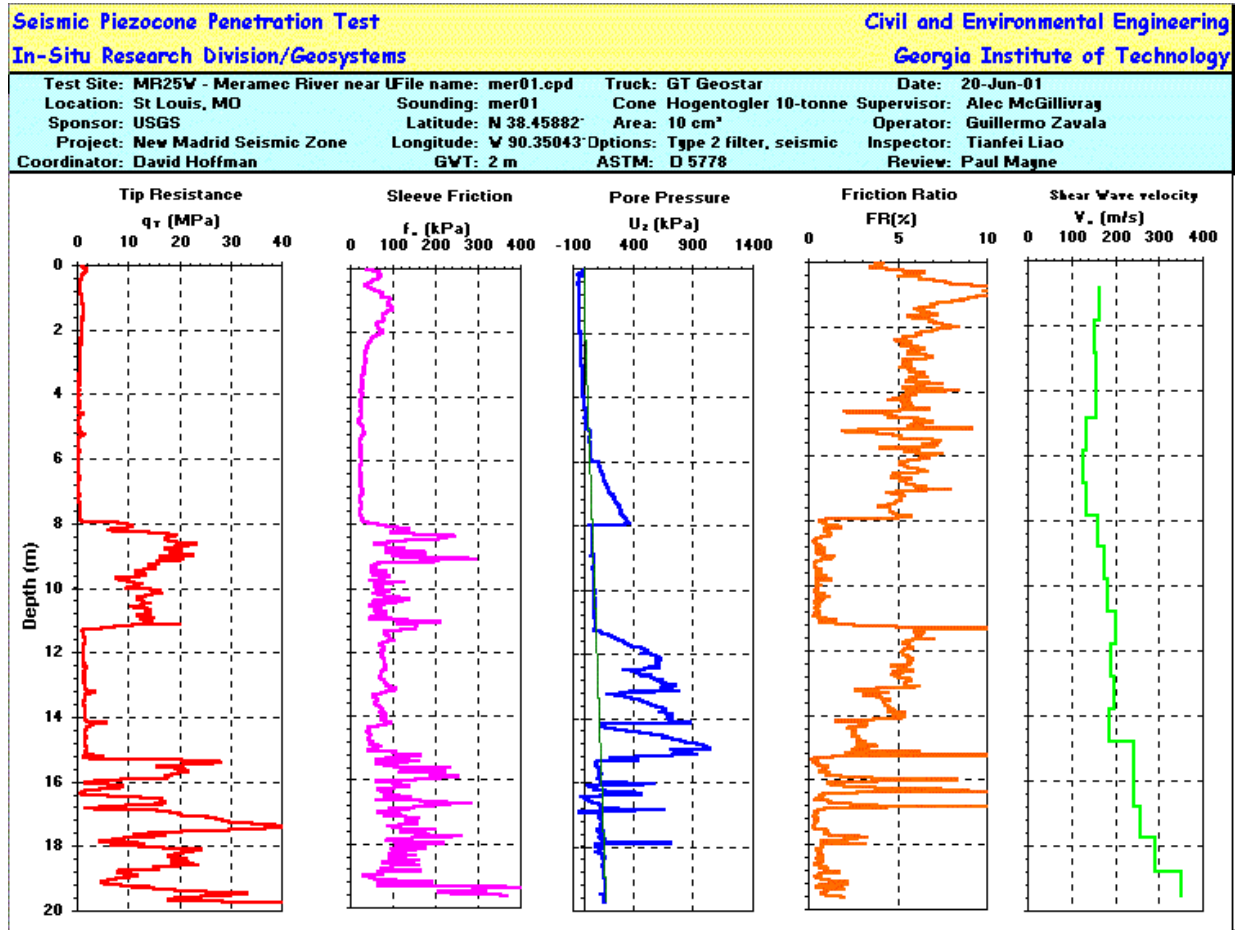
***Investigations:*** Field studies have been performed using cone penetration testing (CPT) to map seismic ground hazards and soil properties at select sites in the Memphis area. During the above time frame, 6 sites have been subjected to multiple CPTs during separate week-long field trips to the region. The sites have been selected and coordinated with the assistance of other USGS researchers (Buddy Schweig, Laurel Mayrose, Martitia Tuttle) and members of the Center for Earthquake Research & Information (CERI - Roy Van Arsdale), state agencies (Dave Hoffman - Missouri State Geologist; Kevin McLain- MoDOT), and the Mid-America Earthquake (MAE) Center (Paul Bodin). The sites include: (1) Wolf River near Shelby Farms; (2) CERI headquarters at the University of Memphis; (3) Mud Island along the Mississippi River; (4) Walker site at Marked Tree, Arkansas, (5) Nodina Site, Arkansas, and (6) Hillhouse site, MO. Additional sites were explored this year under a follow-up grant 01HQGR0039 (Jan. 2001-Dec. 2001) including: (1) Dexter, MO, (2) Meramec River sites near St. Louis, (3) Cape Girardeau with MoDOT; (4) Germantown TN site, and (5) Loosahatchie River in TN. Many of the above sites are recognized as paleoliquefaction sites with evidence of source sands having liquefied during prior seismic events (Tuttle, et al. 1999). At each site, a number of soundings were performed either to assure repeatability of results, or investigate lateral variability across the site, or to obtain different types of exploratory data (dual-element piezocone tests, seismic cone, resistivity profiles, dissipation data).

### ***Results:***

A total of 30 soundings were completed in the Memphis area in March, July, and August of 2000 by our CPT crew. An additional 24 soundings were performed this past year in March, May, and July of 2001. A listing of the test locations, recorded CPT data (both graphical and downloadable files), and liquefaction analyses for select locations is given at:

<http://www.ce.gatech.edu/~geosys/Faculty/Mayne/Research/index.html>

The CPT crew consisted of at least three personnel at any one time, including: Alec McGillivray, Guillermo Zavala, Tianfei Liao, and Billy Camp.



**Figure U-1. Representative SCPTu2 Sounding from Meramac River Paleoliquefaction Site, St. Louis.**

Results from a seismic piezocone penetration test at the one of 2 paleoliquefaction sites found by Dr. M. Tuttle are shown above. This work was completed with collaborative effort by Dave Hoffman of the MO State Geology Department, Houda Jadi, and Professor R. Luna of the Univ. MO-Rolla. The sounding shows a thick clay capping to 8 m with a potentially-liquefiable sand from 8 to 11.4 m underlain by clay to 15.2 m and encountering another sand layer to the extent of the sounding depth at 20 m.

Analyses are ongoing in compiling and assessing the various CPT results that have been collected during these 2 USGS programs together with data obtained for the MAE related projects in the New Madrid Seismic Zone. These include: (1) evaluations of seismic ground hazards at existing built sites and new construction; (2) collection of shear wave data for site amplification studies; and (3) forensic data collection for use in backcalculation of what happened during the prior earthquakes in 1811, 1812, 1450, 900, and 500 A.D., where possible to correlate dating, magnitude, distance, and soil consistency.

The CPT evaluations have been able to provide two separate analyses of liquefaction potential using the normalized cone tip stress ( $q_{t1}$ ) and normalized shear wave ( $V_{s1}$ ). The analyses have been conducted using the traditional approaches based on deterministic methods (Youd, et al. 2001). Results have been reported for the initials series of CPT (Schneider and Mayne, 2000).

More recently, probabilistic methods for evaluating the liquefaction potential of sands and silty sands have been developed for the normalized cone tip resistance (Chen & Juang, 2000; Juang & Jiang, 2000; Juang, et al. 2001) and now these are being implemented to determine probabilities of liquefaction for different magnitude earthquakes in the NMSZ (Liao, et al. 2001).

### ***Presentations***

During the past year, we have made several presentations at technical conferences, symposia, and workshops and noted the support given by the U.S. Geological Survey towards these intentions. These include:

- ☐ Geotechnical Earthquake Engineering in Mid-America, Dec. 7, 2000, Collinville, Illinois.
- ☐ New Developments in Geotechnical Site Characterization, March 15, 2001 in Charlotte, NC.
- ☐ Geotechnical Earthquake Engineering in Mid-America, March 15, 2001, in Memphis, TN.
- ☐ CPT Workshop for FHWA, MoDOT, IL DOT, MN DOT, and Univ. MO-Rolla, May 2001.
- ☐ Enhanced Site Characterization - Course at GeoOdyssey 2001, Blacksburg VA, June 7, 2001.
- ☐ Geotechnical Investigations by Seismic Piezocone, San Juan, Aug. 2001.
- ☐ Evaluating Seismic Hazards by Seismic Cone Tests - SDEE, Oct 8, 2001.
- ☐ Post-Processing of Shear Waves by Cross-Correlation, SDEE'01, Oct. 9, 2001.
- ☐ Geotechnical Earthquake Engineering in Mid-America, Nov. 15-16, 2001, Charleston, SC

### ***Publications and Reports***

During the past year, our submitted papers and reports on the research program include the following:

1. Scheider, J.A. and Mayne, P.W. (2000). Liquefaction response of soils in Mid-America evaluated by seismic cone tests. *Innovations & Applications in Geotechnical Site Characterization*, GSP 97, ASCE, Reston/VA, 1-17.
2. Liao, T., Zavala, G.J., McGillivray, A.V., Camp, W., and Mayne, P.W. (2001). Cone penetration testing for seismic hazards evaluation in Memphis and Shelby County, TN. *Report E20-F47 to USGS Central Region*, March 28, 2001, issued by Georgia Tech Research Corporation, Atlanta GA.
3. Liao, T., Zavala, G.J., Camp, W., McGillivray, A.V., and Mayne, P.W. (2000). Results of seismic piezocone penetration tests performed in Memphis, Tennessee. *Report E20-F34 for USGS Grant 00HQGR0025*, May 12, 2000, issued by Georgia Tech Research Corporation, Atlanta GA.
4. Schneider, J.A., Mayne, P.W., and Rix, G.J. (2001). Geotechnical site characterization in the greater Memphis area using seismic cone tests. *Engineering Geology*, Vol. 62, Issues 1-3, pp. 169-184
5. Liao, T., Mayne, P.W., Tuttle, M., Schweig, E., and Van Arsdale, R. (2001). Liquefaction Evaluation of Soils in the New Madrid Zone by Cone Penetration Testing, submitted to the *Journal of Soil Dynamics & Earthquake Engineering*, in review.
6. Zavala, G.J. and Mayne, P.W. (2001). Post-Processing of Downhole Shear Wave Velocities by Cross-Correlation Method, submitted to the *Journal of Soil Dynamics & Earthquake Engineering*, in review.

In addition, CPT data and graphs and files have been disseminated by email, internet, and CD ROM formats to interested parties and to collaborators of the research conducted in the New Madrid and Charleston SC seismic zones.

**References:**

- Chen, C.J. and Juang, C.H. (2000). Calibration of SPT- and CPT-based liquefaction evaluation methods. *Innovations and Applications in Geotechnical Site Characterization*, Geotechnical Special Publication (GSP) No. 97, ASCE, Reston, VA., 49-64.
- Juang, C.H. and Jiang, T. (2000). Assessing probabilistic methods for liquefaction potential evaluation. *Soil Dynamics and Liquefaction 2000*, GSP No. 107, ASCE Conference, Denver, 148-162.
- Juang, C.H., Chen, C.J., and Jiang, T. (2001). Probabilistic framework for liquefaction potential by shear wave velocity. *Journal of Geotechnical & Geoenvironmental Engineering*, Vol. 127 (8), 670-678.
- Tuttle, M., Chester, J., Lafferty, R., Dyer-Williams, K., and Cande, R. (1999). Paleoseismology study northwest of the New Madrid seismic zone. *Report NUREG/CR-5730*. Division of Engineering Technology, U.S. Nuclear Regulatory Commission, Washington, DC, 190 p.
- Youd, T.L., and Idriss, I.M., et al. (2001). Liquefaction resistance of soils: Summary Report from the NCEER and NSF Workshops. *Journal of Geotechnical & Geoenvironmental Engineering*, Vol. 127 (10), 817-833.

## Non-Technical Summary

### Cone Penetration Testing for Seismic Hazards Evaluation in Memphis and Shelby County, TN

USGS Grant 00HQGR0025 (Feb 2000 to Feb. 2001)

Paul W. Mayne, PhD, P.E.  
Georgia Institute of Technology  
Atlanta, GA 30332-0355

Phone: 404-894-6226; Fax: -2281

Email: [pmayne@ce.gatech.edu](mailto:pmayne@ce.gatech.edu); Internet: <http://www.ce.gatech.edu/~geosys/>

Program Element: CU

Keywords: liquefaction, borehole geophysics, probabilistic seismic hazards, geotechnical, paleoliquefaction, regional seismic hazards

**Investigations:** Field studies have been performed using cone penetration testing (CPT) to map seismic ground hazards and soil properties at select sites in the Memphis area including: (1) Wolf River near Shelby Farms; (2) CERI headquarters at the University of Memphis; (3) Mud Island along the Mississippi River; (4) Walker site at Marked Tree, Arkansas, (5) Nodina Site, Arkansas, and (6) Hillhouse site, MO. Additional sites were explored this year under a follow-up grant 01HQGR0039 (Jan. 2001-Dec. 2001) including: (1) Dexter, MO, (2) Meramec River sites near St. Louis, (3) Cape Girardeau with MoDOT; (4) Germantown TN site, and (5) Loosahatchie River in TN. Many of the above sites are recognized as paleoliquefaction sites with evidence of source sands having liquefied during prior seismic events. At each site, a number of soundings were performed either to assure repeatability of results, or investigate lateral variability across the site, or to obtain different types of exploratory devices.

#### **Results:**

A total of 30 soundings were completed in the Memphis area in March, July, and August of 2000 and an additional 24 soundings were performed this past year in March, May, and July of 2001. A listing of the test locations and recorded CPT data are given at:

<http://www.ce.gatech.edu/~geosys/Faculty/Mayne/Research/index.html>

#### **Publications and Reports**

1. Scheider, J.A. and Mayne, P.W. (2000). Liquefaction response of soils in Mid-America evaluated by seismic cone tests. *Innovations & Applications in Geotechnical Site Characterization*, GSP 97, ASCE, Reston/VA, 1-17.
2. Liao, T., Zavala, G.J., McGillivray, A.V., Camp, W., and Mayne, P.W. (2001). Cone penetration testing for seismic hazards evaluation in Memphis and Shelby County, TN. *Report E20-F47 to USGS Central Region*, March 28, 2001, issued by Georgia Tech Research Corporation, Atlanta GA.
3. Liao, T., Zavala, G.J., Camp, W., McGillivray, A.V., and Mayne, P.W. (2000). Results of seismic piezocone penetration tests performed in Memphis, Tennessee. *Report E20-F34 for USGS Grant 00HQGR0025*, May 12, 2000, issued by Georgia Tech Research Corporation, Atlanta GA.
4. Schneider, J.A., Mayne, P.W., and Rix, G.J. (2001). Geotechnical site characterization in the greater Memphis area using seismic cone tests. *Engineering Geology*, Vol. 62, Issues 1-3, pp. 169-184.